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The effect of prior experience with computers, statistical self-efficacy, and computer anxiety on students' achievement in an introductory statistics course: A partial least squares path analysis

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A Partial Least Squares Path Analysis technique was used to test the effect of students' prior experience with computers, statistical self-efficacy, and computer anxiety on their achievement in an introductory statistics course. Computer Anxiety Rating Scale and Current Statistics Self-Efficacy Scale were administered to a sample of 64 first-year university undergraduates (35 males and 29 females) enrolled in an introductory statistics course in a Faculty of Education. Achievement scores were obtained from students' records. Results of the study revealed that statistical self-efficacy was the most important predictor of students' achievement in statistics, followed by prior experience with computers and finally computer anxiety. In addition, statistical self-efficacy and prior experience with computers had an indirect effect on achievement in statistics through their effect on computer anxiety. Implications of these findings for teaching and learning statistics are discussed.

Prior experience, statistical self-efficacy, computer anxiety, achievement, statistics

INTRODUCTION

Success within the social science disciplines at the university level entails a thorough familiarity with modern statistical methods. Helping university students achieve mastery in statistics represents a major challenge for tertiary educators. Past research efforts have involved redesigning statistics courses (Moore, 1997), enhancing the relevance of statistics (Thompson, 1994), emphasising the importance of salient statistical concepts (Johnson, 1986), developing mathematical ability (Hong, 1999), and encouraging positive attitudes toward statistics (Hogg, 1991; Sorge, 2001).

It is likely that performance in statistics courses is affected by motivational factors such as anxiety and self-efficacy. In addition, prior experience with computers may also be crucial. When students enrol in a statistics course, they need to use computers to run different statistical analyses using a variety of software. Familiarity with computers may thus be seen as a positive or facilitative variable in helping students accommodate to the demands of a statistics course.

On the other hand, computer anxiety may contribute to the students' levels of concern and uncertainty, thereby reducing levels of academic achievement. Awang-Hashim, O'Neil, and Hocevar (2002), for example, found that state anxiety had a significant inverse relation with achievement in statistics. It would seem that anxious individuals devoted cognitive capacity to off-task efforts such as worrying about their performance and that with overloaded memory systems, a person was inclined to make errors (Darke, 1988; Friend, 1982).

Chua and Chen (1997, p.823) defined computer anxiety as "high anxious response towards interaction or anticipated interaction with electronic data processing systems." Maurer and

Simonson (1984) concluded that a person with computer anxiety would exhibit the following behaviours: (a) avoidance of computers, (b) excessive caution when using computers, (c) negative remarks toward computers and computing, and (d) attempts to shorten periods when computers were being used.

Hence, in terms of factors likely to be involved in students' success in a statistics course, it can be suggested that prior experience with computers would be helpful, while high levels of anxiety about computers would be unhelpful.

It is conceivable that the effects of prior experience with computers and computer anxiety on students' achievement in statistics are mediated by their self-efficacy. Meier (1985) applied Bandura's theory of self-efficacy to computer-based learning and confirmed that high levels of computer anxiety reduced levels of self-efficacy, which in turn lowered computer-based performance. Bandura (1982, p.122) defined self-efficacy as "how well one can execute courses of action required to deal with prospective situations." Self-efficacy was hypothesised to influence initiating behaviour, how much effort was applied to attain an outcome, and the level of persistence applied to the task in the face of difficulties and setbacks (Bandura, 1997).

However, it is also conceivable that the impact of self-efficacy on academic achievement is itself mediated by anxiety level. Zimmerman (1995) argued that self-efficacy beliefs aroused anxiety rather than the reverse. Tobias (1992) and Tobias and Everson (1997) indicated that anxiety interacted with metacognitive knowledge to affect performance, particularly on tasks that were more cognitively demanding. Thus, when other achievement motivational components (for example self-efficacy) were examined simultaneously, anxiety tended to play a mediational role in achievement.

The present study was conducted in the context of a first-year university statistics course. The following were investigated: (a) the extent to which students' achievement in statistics would be predicted from measures of their prior experience with computers, statistical self-efficacy, and computer anxiety; (b) whether students' computer anxiety would mediate the relationship between their statistical self-efficacy and achievement in statistics; (c) whether students' computer anxiety would mediate the relationship between their prior experience with computers and achievement in statistics; and (d) whether students' statistical self-efficacy would mediate the relationship between their prior experience with computers and achievement in statistics.

METHODS

Participants

Subjects of the present study included 64 first-year university undergraduates (35 males and 29 females) enrolled in an introductory statistics course in a Faculty of Education in 2004. The median age was 18.4 years. Participation was voluntary, and four students enrolled in the course declined to participate in data collection.

Measurements

Computer Anxiety Rating Scale (CARS)

The CARS (Heinssen, Glass, and Knight, 1987) is a 19-item scale that assesses the respondents' cognitions and feelings about their abilities related to the usage of computers. An example of items from the CARS includes "I am confident that I can learn computer skills."

Each item in the CARS was scored on a five-point Likert-type scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). The scoring of nine items (Items 2, 4, 5, 6, 7, 9, 10, 17, and 19) on the scale was reversed so that high total scores represented high anxiety. Scores ranged from 19 (low level of computer anxiety) to 99 (high level of computer anxiety). Within the current data set, the reliability index using Cronbach alpha was 0.67.

Current Statistics Self-Efficacy Scale (CSSES)

The CSSES (Finney and Schraw, 2003) is a 14-item scale that assesses the respondents' confidence in their ability to solve specific tasks related to statistics. An example of the CSSES includes "I can interpret the probability value (p-value) from a statistical procedure." Each item in the CSSES was scored on a five-point Likert-type scale ranging from 1 (No confidence at all) to 6 (Complete confidence). Scores ranged from 14 (low level of statistical self-efficacy) to 84 (high level of statistical self-efficacy). Within the current data set, the reliability index using Cronbach alpha was 0.65.

Procedures

The CARS and the CSSES were administered in the fourth week of the statistics class. In addition, participants responded to a question concerning their prior experience with computers on a five-point scale ranging from 1 (Slightly experienced) to 5 (Very experienced). Students were asked for a permission to obtain their achievement scores from their records. These scores were the course aggregated total score, that is, the sum of on-course assignments and examinations scores and were expressed as percentages.

PATH ANALYSIS

PLSPATH, a DOS based program, was developed by Sellin (1989) and was based on the Partial Least Squares (PLS) procedure introduced by Wold (1985). Sellin described PLSPATH as a general technique for estimating path models involving latent constructs indirectly observed by multiple indictors. The PLS procedure was related conceptually to principal component analysis and regression analysis and it was argued to be appropriate for small sample sizes (Sellin and Keeves, 1997).

The PLS procedure calculates an estimate for each construct or latent variable, which is derived from corresponding observed or manifest variables, thus partitioning the hypothesised inner model into its component constructs. The PLS technique has been described as a soft-modelling approach and was argued to be useful in the investigation of causal-predictive analysis rather than confirmatory analysis (Sellin and Keeves, 1997). Keeves (1986) compared PLS with other structural equation modelling (SEM) approaches, such as LISREL, and concluded that PLS provided the most flexible and appropriate approach for analysis of data in the International Association for the Evaluation of Educational Achievement (IEA) project.

The model in the present study incorporates three types of constructs: (a) antecedents variables, which include students' prior experience with computers as an exogenous variable that is not influenced by other variables in the model; (b) mediator variables, which include students' computer anxiety and statistical self-efficacy; and (c) criterion variables, which include students' achievement in the statistics course as being predicted by the other variables in the model.

The main consideration guiding the development and refining of the model was based on a parsimonious attempt to build a concise and coherent model. Certain assumptions were set during the process of model development: (a) prior experience with computers was positively related to statistical self-efficacy and negatively related to computer anxiety; (b) statistical self-efficacy was negatively related to computer anxiety; and (c) achievement in statistics, as the criterion measure, was considered to be under the influence of all other variables in the model either directly or when mediated through other variables. The positive (+) and negative (-) effects of prior experience with computers, statistical self-efficacy, and computer anxiety on achievement in statistics are presented in Figure 1.

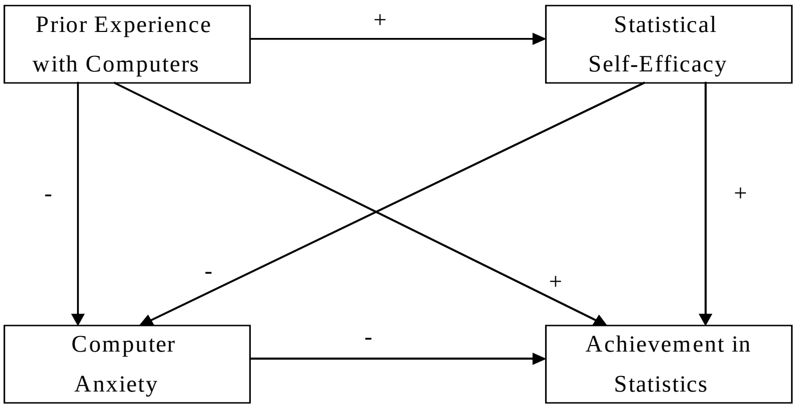

Figure 1. Hypothesised PLS path model

RESULTS

Initially, a matrix of Pearson product-moment correlation coefficients, presented in Table 1, among prior experience with computers, computer anxiety, statistical self-efficacy (predictors) and achievement in statistics (criterion) scores was calculated. Means and standard deviations were also estimated.

Table 1. Correlations and descriptive statistics of prior experience with computers, computer anxiety, statistical self-efficacy and achievement in statistics (N = 64)

Variables	1	2	3	4
1. Prior experience with computers	-			
2. Computer anxiety	- 0.59	-		
3. Statistical self-efficacy	0.25	- 0.67	-	
4. Achievement in statistics	.49	- 0.54	0.57	-
M	4.0	49.0	58.7	56.0
SD	1.8	20.0	25.5	20.0

Note: All reported correlations are significant, $p < 0.05$

It is noted from Table 1 that all variables are moderately or strongly correlated and the highest correlation is between computer anxiety and statistical self-efficacy (r = -0.67). Achievement in statistics has a positive relationship with statistical self-efficacy (r = 0.57) and prior experience with computers (r = 0.49), whereas it has a negative relationship with computer anxiety (r = -0.54). Prior experience with computers has a positive relationship with statistical self-efficacy (r = 0.25), whereas it has a negative relationship with computer anxiety (r = -0.59).

PLSPATH (Sellin, 1989) was used to calculate the standardised path coefficients (betas) and the corresponding jackknife estimates of the standard errors (SE). The SE for each standardised path coefficient is shown in brackets in Figure 2. The residuals or the disturbances are given by $\sqrt{1 - R^2}$ where R^2 is the squared multiple correlation coefficient for a certain latent variable.

Values of direct paths

Table 2 shows that with the exception of the path coefficient (β = 0.25), presented by a dashed line, from prior experience with computers to statistical self-efficacy, all the hypothesised direct paths are significant ($p < 0.05$). The jackknifing method (Sellin, 1989) was applied to estimate the jackknifing standard errors.

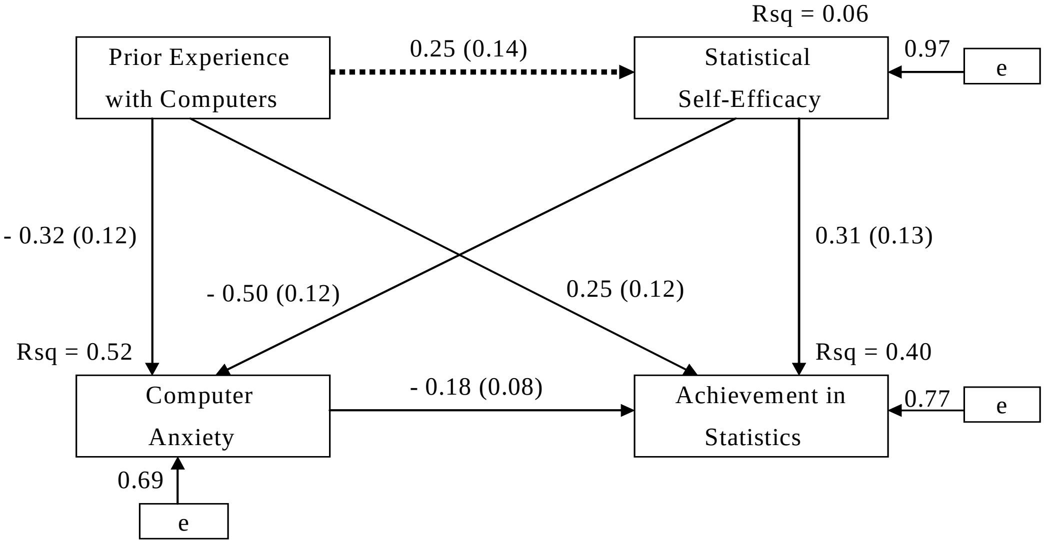

Figure 2. Initial PLS path model of the effect of prior experience with computers, computer anxiety, and statistical self-efficacy on achievement in statistics

As an accepted rule, a path coefficient is considered to be statistically significant when twice the corresponding jackknife estimate of the standard error is less than the value of the standardised direct path coefficient (beta) (Falk and Miller, 1992; Sellin and Keeves, 1997). The factors with the single largest direct effect on achievement in statistics is statistical self-efficacy (β = 0.31), followed by prior experience with computers (β = 0.25) and computer anxiety (β = -0.18) with R^2 = 0.40 indicating that the model explains 40 per cent of the variance of achievement in statistics. Prior experience with computer (β = -0.32) and statistical self-efficacy (β = -0.50) are found to predict computer anxiety with R^2 = 0.52 indicating that those two variables explain 52 per cent of the variance of computer anxiety.

Values of indirect paths

Table 2 shows that prior experience with computers (β = 0.06) and statistical self-efficacy (β = 0.09) have positive indirect effects on achievement in statistics through their effects on computer anxiety. The total effect of a latent variable on another latent variable is calculated by adding the direct and the indirect effect of a certain latent variable in the model.

Refining the model

The modification of the model involves the trimming of all paths that do not contribute significantly to the variance explanation in a latent variable in order to obtain a parsimonious model. When the value of the standardised direct path coefficient is less than twice its corresponding jackknife estimate of the standard error, the path should be removed (Sellin and Keeves, 1997). Paths meeting this criterion were trimmed from the model. Since the value of the standardised path coefficient from prior experience with computers to statistical self-efficacy was less than twice its corresponding jackknife estimate of the standard error (SE), this path was removed by setting the value of the path to zero in the PLSPATH program trimming editor. Figure 3 shows the final model that consists of students' prior experience with computers and statistical self-efficacy as exogenous variables, computer anxiety as a mediator, and academic achievement in statistics as a criterion. The SE for each path coefficient is shown in brackets. The residuals or the disturbances are given by $\sqrt{1-R^2}$ where R^2 is the squared multiple correlation coefficient for a certain latent variable.

Table 2. Jackknife results of PLS path model of the effect of prior experience with computers, computer anxiety, statistical self-efficacy on achievement in statistics (N = 64)

Paths	JknStd	Beta (β)	Indirect Effects	Total
To statistical self-efficacy (R^2 = 0.06)				
• Prior experience with computers	0.14	0.25	0.00	0.25
To computer anxiety (R^2 = 0.52)				
• Prior experience with computers	0.12	- 0.32	0.00	- 0.32
• Statistical self-efficacy	0.12	- 0.50	0.00	- 0.50
To achievement in statistics (R^2 = 0.40)				
• Prior experience with computers	0.12	0.25	0.06	0.31
• Statistical self-efficacy	0.13	0.31	0.09	0.40
• Computer anxiety	0.08	- 0.18	0.00	- 0.18

Note: JknStd = Jackknife standard error. All tests are two-tailed because of the nondirectional nature of the hypotheses. A value of 0.00 indicates that the value was not obtained.

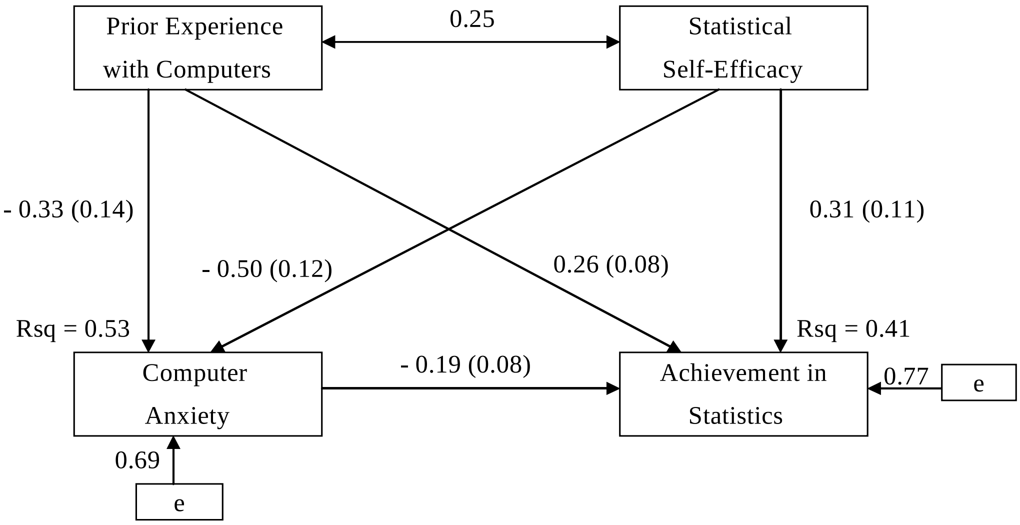

Figure 3. Re-estimated PLS path model of the effect of prior experience with computers, computer anxiety, statistical self-efficacy on achievement in statistics

Values of direct paths

Table 3 shows that all direct paths are statistically significant ($p < 0.05$) since twice the corresponding jackknife estimate of the standard error is less than the value of the standardised direct path coefficient (Falk and Miller, 1992; Sellin and Keeves, 1997). Statistical self-efficacy (β = 0.31) has the largest direct effect on achievement in statistics followed by prior experience with computers (β = 0.26) and computer anxiety (β = -0.19) with R^2 = 0.41 indicating that the model explains 41 per cent of the variance of achievement in statistics. Prior experience with computers (β = -0.33) and statistical self-efficacy (β = -0.50) were found to predict computer anxiety with R^2 = 0.53 indicating that those two variable explain 53 per cent of the variance of computer anxiety.

Values of indirect paths

Table 3 shows that prior experience with computers (β = 0.06) and statistical self-efficacy (β = 0.1) have positive indirect effects on achievement in statistics through their effect on computer anxiety. The total effect of a latent variable on another latent variable is calculated by adding the direct and the indirect effect of a certain latent variable in the model.

Table3. Jackknife results of a re-estimated PLS path model of the effect of prior experience with computers, computer anxiety, statistical self-efficacy on achievement in statistics (N = 64)

Paths	JknStd	Beta (β)	Indirect Effects	Total
To computer anxiety (R^2 = 0.53)				
• Prior experience with computers	0.14	- 0.33	0.00	- 0.33
• Statistical self-efficacy	0.12	- 0.50	0.00	- 0.50
To achievement in statistics (R^2 = 0.41)				
• Prior experience with computers	0.08	0.26	0.06	0.32
• Statistical self-efficacy	0.11	0.31	0.1	0.41
• Computer anxiety	0.08	- 0.19	0.00	- 0.19

Note: JknStd = Jackknife standard error. All tests are two-tailed because of the nondirectional nature of the hypotheses. A value of 0.00 indicates that the value was not obtained.

DISCUSSION

This study has used the path analysis program, PLSPATH, to test a casual model of the factors that affected students' achievement in an introductory statistics course. Findings of the study have shown that among the many factors that might contribute to students' achievement in statistics, statistical self-efficacy was the strongest. After considering students' computer anxiety and prior experience with computers, statistical self-efficacy remained a critical factor that affected directly students' achievement in statistics. Students who entered the statistics course with high levels of self-efficacy appeared to exhibit high scores on the overall course aggregate. These findings support Bandura's social learning theory and are consistent with the body of research implicating self-efficacy as a significant factor influencing academic achievement (Bandura, 1977, 1986, 1997; Schunk, 1995; Schunk and Pajares, 2002).

Besides the direct effect, the analysis showed that statistical self-efficacy could also influence achievement in statistics indirectly by reducing students' anxiety about computers. Computers have been recognised as important facilitators in statistics courses that helped students meet the requirement of such classes. Research on the psychological effect of technology has shown that computer anxiety might impair students' performance because anxious students devoted some level of their cognitive capacities to off-task effort such as worrying about their performance (Darke, 1988; Friend, 1982). The results suggest that feelings of competency in statistics can serve to counteract students' worries about using computers to meet the upcoming demands of their statistics course. These findings are supported by what other research studies indicated that anxiety interacted with metacognitive knowledge to affect performance, particularly on tasks that were more cognitively demanding such as mathematics and statistics. Thus, when other achievement motivational components (for example, self-efficacy) were examined simultaneously, anxiety tended to play a mediational role in achievement (Bandura, 1986; Tobias, 1992; Tobias and Everson, 1997).

Another important factor that was found to affect students' achievement in statistics was prior experience with computers. It was apparent that students' familiarity with computers assisted their performance in a statistics class that required the use of computers to run different statistical analyses using a variety of software. Furthermore, when students had experience with computers, they were more likely to be less anxious about using the computer as a statistical analysis tool. The current findings stand on line with those of Lolyd and Gressard (1984) who reported that students became less anxious once an initial trauma period passed through a prior experience (see also Howard and Smith, 1986; Glass and Knight, 1988).

In summary, the results of the PLS path analysis add further support to the notion that learning is a complex process, and that causal models can be developed to represent it. This study demonstrated the direct and indirect relationships between certain measurable factors and achievement in statistic. What the data also indicated, however, was that taking in consideration students' prior experience with computers and computer anxiety, the strongest predictive factor of achievement in learning statistics remained statistical self-efficacy.

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